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RESEARCH ARTICLE

Insect pests and their role as biocontrol agents on populations of *Impatiens glandulifera* in Bulgaria – a case study

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Abstract

Based on data from available scientific publications, a review of the insects, trophically related to *Impatiens glandulifera* in its European invasion zone has been made. As a result, nine insect species (*Pristerognatha fuligana*, *Deilephila elpenor*, *Xanthorhoe biriviata*, *Chrysolina herbacea*, *Siobla sturmi*, *Impatientinum asiaticum*, *Aphis fabae*, *Aphis nasturtii*, *Phytoliriomyza melampyga*) were found on the invasive plant. Of the identified insects, seven species (*D. elpenor*, *X. biriviata*, *A. fabae*, *A. nasturtii*, *C. herbacea*, *P. fuligana*, *P. melampyga*) are widespread in the country, of which only two – *C. herbacea* and *P. fuligana* are associated with *I. glandulifera*. The remaining two (*I. asiaticum* and *S. sturmi*) are not presented in the Bulgarian entomofauna. The potential role of these insects as agents of biological control of populations of *I. glandulifera* in Bulgaria has been assessed.

Keywords

Himalayan balsam, insects, biological control agents, trophic connections

Introduction

Impatiens glandulifera Royale (commonly known as Himalayan balsam) is an annual weed, which is native to the Himalayas and invasive in Europe, Asia (Russian Far East and Japan), North America, Japan and New Zealand (Adamowski, 2008). It often forms monotypic stands along the river banks and water flow. Due to its tall stature

and high rate of reproduction, it can dominate the local vegetation over a short period of time, which prevents the establishment of native plants and makes stream banks vulnerable to erosion (Sheppard at al., 2006; Clements at al., 2008). In Bulgaria, *I. glandulifera* occurs mainly in the riparian zones, where its invasion affects local species diversity and soil nutrient composition (Kachova et al., 2020; Glogov, Georgieva, 2020; Glogov et al., 2020, Georgieva, 2021).

In the literature, few possible methods for control or elimination of populations of *I. glandulifera* are known: manual and mechanical control (Hartmann et al., 1995; Tanner, 2011), chemical control (Wadsworth et al., 2000) and biological control (Wood et al., 2020). The manual and mechanical control refers to a technique, which involves the cutting of plants below the first node to avoid regrowth and plant removal (Rapid, 2018). Their application leads to river bank erosion and disturbance of an already depleted mycorrhizal network, caused by its invasion (Tanner, 2011; Tanner et al., 2017). Chemical control involves the application of chemicals (herbicides) to weeds or soil to control the germination or growth of the weed species. Chemical herbicides are used and can be effective, but are restricted close to the water courses (Kelly et al., 2008). Both methods are often difficult to apply in the infested area because the plant grows in inaccessible areas or sites of high conservation status, where chemical and/or manual control is not an option. The biological control is an environmentally friendly and effective mean of reducing or mitigating invasive plants. It involves the use of natural enemies (plant pathogens or arthropod species) from the plant's native range in the regulation of host populations within the introduced/invasive range (DeBach, 1964). A good example of biocontrol against *I. glandulifera* is the introduction of the rust fungus *Puccinia komarovii* var. *glandulifera* in the UK from its native range (in western Himalayas) (Tanner et al., 2015).

Local enemies are also potential regulators on the invasive plants. According to The Enemy Release Hypothesis (ERH), a species will be successful in a new habitat when its former enemies (e.g., insects) are not present (Keane, Crawley, 2002). Most research supports this idea, but others suggest that it is not always correct. Najberek et al. (2017) provide evidence, that in the mountains in the Czech Republic, the invasive alien species *I. glandulifera* tended to be more attacked from pests than the native species *Impatiens noli-tangere* L. In another garden experiment by Kollmann et al. (2007), for the first time a viral infection found by *I. glandulifera* in various European regions has been reported, which has led to reduce above-ground biomass of the invasive species. Based on the above statements, we tend to accept Najberek's (2017) claim, that the success of the ERH depends on various factors, the significance of which varies depending on the biotic and / or abiotic conditions of the place where the plant is introduced. The latter raises the question of establishing the role of local enemies on the Himalayan balsam populations in its invasion areas. This requires paying more attention to diseases on *I. glandulifera* and insect pests in field research and planning future experiments.

The aim of this study is to identify the insects, trophically associated with *I. glandulifera* in Europe, as well as to determine their potential role as natural regulators of the invasive plant in the country.

Materials and methods

An up-to-date list of insects, trophically related to *I. glandulifera* in Europe has been made, using available information from local and foreign publications. Data on the food specialisations of insects are also presented, as well as the type of damage that they cause on the Himalayan balsam. Based on the received information, a preliminary assessment of the role of insects, as a possible regulator of *I. glandulifera* for the country, was made.

Results

General. Based on a review of European literature, only nine insect species, trophically associated with *I. glandulifera*, have been identified, as follows – order Lepidoptera: fam. Tortricidae (*Pristerognatha fuligana* (Denis & Schiffermüller, 1775), fam. Sphingidae (*Deilephila elpenor* (Linnaeus, 1758), fam. Geometridae (*Xanthorhoe biriviata* (Borkhausen, 1794)); order Coleptera, fam. Chrysomelidae (*Chrysolina herbacea* (Duftschmid, 1825)); order Hymenoptera: fam. Tenthredinidae (*Siobla sturmi* (Klug, 1817)); order Hemiptera: fam. Aphididae (*Impatientinum asiaticum* Nevsky, 1929 and *Aphis fabae* Scopoli, 1763, *Aphis nasturtii* Kaltenbach, 1843); order Diptera: fam. Agromyzidae (*Phytoliriomyza melampyga* (Loew, 1869)) (Table 1).
Entomofauna. From the list of identified insects in the region of the European countries, two species (*S. sturmi* and *I. asiaticum*) are currently unknown for the Bulgarian fauna. The other seven species – *D. elpenor* (Pittaway, 1993), *X. biriviata* (Kostova et al., 2019), *A. fabae* (Yovkova et al., 2013; Pencheva et al., 2014), *A. nasturtii* (Yovkova et al., 2013), *C. herbacea* (Gruev, Tomov, 2007), *P. furigana* (Velcheva, 2000) and *P. melampyga* (Buhr, 1941) are spread in the country and they can be potential pests on the invasive plant.
Connections in Bulgaria. Until now in the entomological literature, two species – *C. herbacea* (Belilov et al., 2020) and *P. furigana* (Zaemdzhikova et al., 2020), have been identified on the Himalayan balsam. The other five species (*D. elpenor*, *X. biriviata*, *A. fabae*, *P. melampyga* and *A. nasturtii*) have not been found yet.
Food specialisation. The majority of the total number of identified insects is mono- and oligophagous (7 species), while two species (*A. fabae* and *A. nasturtii*) are polyphagous (Table 1).

Discussion

Low species richness of insects (9 species), trophically associated with *I. glandulifera* has been found in its European invasion area, of which seven species are distributed in Bulgaria. In its natural range in the Himalayas, 32 distinct arthropods species were reported by Turner (2011) on the Himalayan balsam, which is significantly more than

Table I. List of insects, trophically related to *Impatiens glandulifera* in Europe

Species	Food specialisation	Damages	
		Type	References
Siobla sturmi [1]	strictly oligophagous	larvae feed on leaves	Schmitz, 2007; Chevin et al., 2011
Pristerognatha fuligana *	monophagous	larvae live and feed on the stem	Meert, Nossen, 2019; Burkhart, Nentwig, 2008; Zaemdzhikova et al., 2020**
Xanthorhoe biriviata [2]		larvae feed on plant leaves	Schmitz, 2007
Chrysolina herbacea *		unknown	Belilov et al., 2020**
Phytoliriomyza melampyga [2]		larvae form a distinctive green leaf mine	Buszko, 2015
Impatientinum asiaticum [1]		nymphs and adult forms cause deformations on leaves, shoots and flowers. They are a vector for phytopathogenic viruses and fungal pathogens.	Starý, Havelka, 2014
Aphis nasturtii [2]	polyphagous		
Aphis fabae [2]			
Deilephila elpenor [2]	oligophagous	larvae feed on plant leaves	Beerling, Perrins, 1993

[1] insects – absent in Bulgaria
[2] insects – known for the Bulgarian entomofauna, but are not associated with *I.glandulifera*
* insects, trophically related to *I. glandulifera* in Bulgaria / ** first country reporting

the trophically associated species in Europe. Non-native species are expected to have a lower species richness of pests than the native ones (Omoro et al., 2011), which can explain their low number in Europe. It should be noted, that the share of monophagous insects (they feed on a single plant taxon) is higher than the polyphagous, which consume plant tissues from different botanical families. Due to the wide range of hosts, polyphages are expected to be of greater impact for the abundance of *I. glandulifera*, especially in the colonisation of new habitats, where the specialised enemies are absent. Conversely, the role of monophagous insects after colonisation is expected to increase. This is consistent with the share of mono- and polyphagous egg parasitoids in newly and old colonised habitats of *Thaumetopoea pityiocampa* (Den. & Schiff.). In the new habitats polyphagous parasitoids are dominant and vice versa, in the old ones monophagous parasitoids dominate (Mirchev et al., 2021).

In Bulgaria, only two insect species, *Pristerognatha fuligana* (Zaemdzhikova et al., 2020) and *Chrysolina herbacea* (Belilov et al., 2020), are associated with the Himalayan balsam. *C. herbacea* (green mint beetle) is a monophagous species that feeds on various taxa of Lamiaceae (Mentha spp., *Thymus* spp.), with a preference for mint plants (Çağrı et al., 2015). It is native to the European region (Al-Nadawi, 2019). In Turkey it is aggressive invasive species, which causes severe damages to various wild and cultivated varieties of mint (Tarla, Tarla, 2017). The damage they cause can be direct or indirect. Direct damage is caused by the feeding of larvae, which pierce the leaves of plants. The indirect damage is the result of loss of leaf mass, which leads to a reduction in the process of photosynthesis and reduced growth, which can cause the

plant's death (Al-Nadawi, 2019). For the country in a study of Belilov et al. (2020), two larvae of *C. herbacea* on the leaves of *I. glandulifera* were observed, which contradicts the eating habits of the insect. On the one hand, this can be an example of an accidental coexistence between the insect and host plant. This is expected for adults, which might have accidentally come across the invasive plant, but is atypical for their larvae. On the other hand, it is also possible the mint beetles (adults and larvae) to be attracted by the smell of *I. glandulifera*, especially in habitats with low population density of the main food plant. This corresponds to the observation of Belilov et al. (2020), who reported low population density of mint plants in the test plot – less than 7%. In any case, further studies are needed to confirm the observed trophic link in the country.

The tortrix moth, *P. fuligana* is found in Eastern Europe and spreads to the East Palaearctic region as far as Japan, howevr it is not known in its native distribution range of Himalaya (Razowski, 2003; Burkhart, Nentwig, 2008). In the literature, the Himalayan balm is a well-known food plant for the tortrix moth, but only in three European countries: Belgium (Meert, Nossent, 2019), Switzerland (Burkhart, Nentwig, 2008) and also in Bulgaria (Zaemdzhikova et al., 2020). The adults of *P. fuligana* fly between April and August, suggesting two generations a year (Razowski, 2003). The larvae live in the stem of infested plants. Pupation takes place within the larval habitat. Before hatching, the pupa protrudes from the stem through a prepared exit hole (Meert, Nossent, 2019). The plant regenerates easily, which helps to quickly close holes from caterpillars feeding, thus also preventing its further infection by pathogens. In a study of Burkhart & Nentwig (2008) was reported that *P. fuligana* had no effect on the Himalayan balsam, i.e. the plant was not affected by the feeding of the caterpillars. They used the stems only as a food source until they complete their development in them (Burkhart, Nentwig, 2008). A similar result was reported from Bulgaria by Zaemdzhikova et al. (2020). In the area of Plana and Lozenska Mts., the species is present with low density in the sample plots and does not cause damage to the invasive plant.

The other insects, *A. fabae*, *A. nasturtii*, *P. melampyga*, *D. elpenor* and *X. biriviata* are spread in the country, but have not been found in the stands of *I. glandulifera*. Both aphids are polyphagous. They have a broad host range, affect various field crops, wild plants, fruit trees and vegetables (Wilkinson, Douglas, 2007; Fericean, Corneanu, 2017). Worldwide, the aphids are one of the major problems to plants for two reasons: aphid feeding can cause direct damages by extracting sap and indirectly by sending a large number of phytopathogenic viruses. The damages are manifested in – twisting the leaves, deformations on the leaves, shoots and flowers, as well as slowing down the growth of heavily infested plants. The leaf-miner fly *P. melampyga* is very common in Europe (Černý, 2018). The larvae of this fly form a narrow linear mine on the leaves of *Impatiens* spp., which later grows into a large irregular whitish blotch (Buszko, 2015). The larvae of lepidopteran species (*D. elpenor* and *X. biriviata*) are well known to feed on *Impatiens* plants (Bortolin et al., 1998; Schmitz, 2007).

The monophagous insects – *I. asiaticum* and *S. sturmi* are absent from the Bulgarian fauna, but they are well known in other European countries. The aphid species *I. asiaticum* originates from Central Asia. It was introduced into Europe around 1967. Now it is widely spread in Europe, e.g. the Czech Republic, Poland, Russia, Britain, Germany, Denmark, Sweden and Finland (Ripka, Ssiszar, 2008). In Europe it lives all year round on the invasive Himalayan balsam (Starý et al., 2014) and especially on the small balsam (*Impatiens parviflora* DC.) (Eliašová, 2011). The damage that it causes is typical of aphids – it feeds on the undersides of leaves along the main veins and on the flower stalks. The sawfly, *S. sturmi* (= *Tenthredo sturmii* Klug, 1817) occurs in Hungary (Haris, 2020), Belgium, Switzerland, Germany, France (Lisston, 1995), etc. It is a narrow monophagous of *I. noli-tangere* (Liston, 1995; Chevin et al, 2011), while its larvae are also known to consume the leaves of *I. glandulifera* (Schmitz, G. 2007).

Given that these insects are closely specialised in their choice of host plants, it is quite possible that their absence in the country is due to the limited research on local enemies of I. glandulifera. This may also explain the limited number of trophic connections that have been registered so far.

Conclusion

A review of the European literature has shown that for most of the reported insects (with the exception of *P. fuligana*) there is no assessment of the damage they can cause to *I. glandulifera* populations. Further research is needed to determine their role as biological control agents for the invasion of Himalayan balsam in Europe.

With regard to Bulgaria, the ecological role of *I. glandulifera* in riparian zones has been underestimated so far, which may explain the limited number of studies focused on the control of this highly aggressive species.

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